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TO TEACHERS AND PARENTS.

THIS little work, as its title indicates, is designed for use in the common schools of our widely-extended and agricultural country. It has been the especial aim of the author to make it interesting, as well as instructive; and, for the attainment of that purpose, a series of simple, and in some instances brilliant experiments, have been introduced. The apparatus required for the exhibition of the experiments given will be found of the most simple character: a few tumblers and wine-glasses, pieces of glass and metallic tubes, three or four wide-mouth, quart, flint-glass bottles, a few Florence-oil flasks or betties, well cleansed, India rubber in sheet, or tube, for connections, &c., an alcohol or spirit lamp, retort stand, and one or two tubulated retorts, is about all the apparatus essentially necessary.

Of the importance of this department of study there can be but one opinion, when it is remembered that more than four-fifths of the capital of all civilized nations is devoted to the purposes of agriculture, and that the subsistence of all must be ever derived from the soil.

It has been well said, that he who makes two blades of grass to grow where but one blade grew before is a public benefactor: *this* it is the attribute of agricultural chemistry to perform, and *this* is daily accomplished by every enlightened and scientific cultivator of the soil.

May we not anticipate the time when the soil, cultivated in obedience to the fixed and immutable principles of chemistry, shall be made vastly more productive, and in the same proportion more profitable to the farmer? And should we not diffuse, as generally as possible, that knowledge upon which these results are alone dependent?

It has been supposed that the principles of chemistry, as applicable to agriculture, were too complicated to be understood by any but those who had, to some considerable extent, attained a knowledge of inorganic chemistry; and we presume that this impression, notwithstanding its fallacy, may have deterred authors and teachers from making any definite efforts in that direction.

Assured that children may be early and effectively instructed in the elementary principles of chemistry, as they are applicable to agriculture, the author has been induced to prepare this little volume, in the hope of aiding the teacher in an important field of his professional labors, and at the same time interesting and permanently benefiting his classes. A single hour, twice or thrice a week, may be profitably devoted to the study of agricultural chemistry; and it will be a matter of agreeable surprise to observe how readily, and to what an extent, these important principles will be attained and remembered by the child.

The exclusion of scientific and technical terms has not been deemed advisable. It is more advantageous for the pupil, and no more troublesome for the instructor, to teach the elements of science scientifically and correctly, than to convey his instructions in language unscientific, and often inappropriate.

This little volume makes no pretensions to literary excellency, or to scientific completeness; indeed, it is only designed as an entrance to the rich mines of interest and wealth which chemistry, applied to agriculture, offers to all who are her diligent students. The author may should the friends of an advanced and elevated education think it advisable, at some future time prepare a more extended and scientific work on this important branch of the true "wealth of nations."

In the mean time, "The First Lessons in Chemistry and Geology" is submitted to the teachers and the friends of education in the United States; and, if it should be instrumental in awakening an interest, and promoting the study of agricultural chemistry, and thereby fitting our youth for a more scientific and remunerating cultivation of the soil, its author's labor will not have been undertaken in vain, nor his efforts pass without their reward.

J. E. Kent, M. D.

Pawtucket, R. I.

FIRST LESSONS

IN

CHEMISTRY AND GEOLOGY,

APPLIED TO AGRICULTURE.

MAN, and the varied tribes of animal life, derive their subsistence from the earth. Almost all its productions grow spontaneously, but nearly all of those productions may be greatly improved by appropriate cultivation. The cultivation of the soil is called agriculture, and the cultivator is an agriculturist, or farmer.

The farmer has two ends to attain: 1. To improve, by cultivation, the natural products of the soil; and, 2. To secure the largest crops at the smallest cost, with the greatest saving of labor, and with the least injury to the land.

Questions.—**From whence do man and animals derive their subsistence? What is agriculture? What is a cultivator of the soil called?**

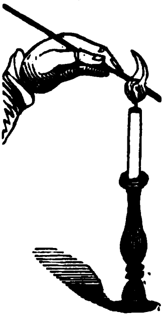
To insure these very desirable results, the farmer should know the nature of the crops he raises, the character and constituents of the soil on which they are grown, and the manures most suitable to prevent exhaustion of the land; and unless he possesses, to some practical extent, these several kinds of knowledge, he can never become a successful and profitable cultivator of a farm. Without this knowledge, his land will soon become unproductive and non-remunerative, notwithstanding it may be frequently manured and laboriously worked. This knowledge is called Agricultural Chemistry.

THE CONSTITUENT NATURE OF THE PRODUCTIONS OF THE SOIL.

All forms of vegetable existences, all the productions of the earth, consist of two parts, *organic* and *inorganic* matter; the organic part, if put into the fire, burns away, — the inorganic part cannot be burned up. (See Appendix, 1.)

Questions. — **What ought the farmer to know, in order successfully and profitably to cultivate the soil? What is this knowledge called? Of what kinds of matter do vegetable productions consist? Which part is combustible? *Which* will not burn away? What is the part called which *burns? What that* which will not burn?**

Fig. 1.



In all vegetable substances, the organic or combustible part is very much the largest; it makes from ninety to ninety-nine parts out of every hundred of their weight.

The organic parts of all vegetable substances consist of four elements; these elements are called carbon, hydrogen, oxygen, and nitrogen: they are called elements, or elementary bodies, because they have never yet been divided or decomposed.

CARBON is a solid substance, generally of a black color; it has no taste or smell; usually burns very rapidly, and gives out much heat. Common charcoal, coke,—the substance left in retorts after the gas has been distilled from the coal,—lamp-black, black-lead, and the costly and brilliant diamond, are only different varieties of carbon.

HYDROGEN is found only in the form of a

Questions.—Of which do vegetables contain the most? State the proportions. Of what is the organic part of plants composed? Why are they called elementary bodies? What is carbon? Name some of its varieties. What is *hydrogen?*

gas, or of a kind of air. It burns as coal-gas does, but its flame is blue, and gives a very

Fig. 2.

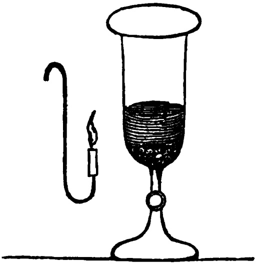
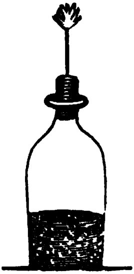


Fig. 3.



feeble light. Its name, from the Greek, means water-maker. A candle will not burn, nor can any animal live, in hydrogen gas. Mixed with common air, it explodes with great violence when brought into contact with flame. It is the lightest of all known substances. The gas burned in the streets and houses is hydrogen, mixed with a peculiar kind of carbon. The explosions in coal-mines are caused by a mixture of hydrogen and other gases with the air we breathe, which are set on fire by the lamps used

Questions.—What does the name hydrogen signify? What its effects on animal life? Will it burn? Describe any other of its properties.

by the miner. Hydrogen is one of the constituents of water. (See Appendix, 3.)

Fig. 4.

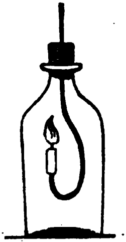
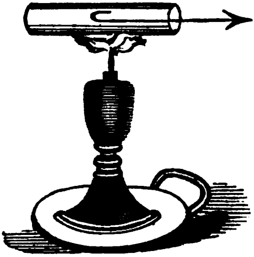


Fig. 5.



OXYGEN is also a gas. A taper burns with increased brilliancy in oxygen. It was at first called vital air. It is heavier than hydrogen, and heavier than the atmosphere. The air we breathe contains one-fifth of its bulk of oxygen. Its name means acid-maker. It combines with a great many substances, forming oxides: the rust on iron is caused by oxidation, and most earths are only metals in different degrees of oxidation. Oxygen is one of the constituents of water. It

Questions. — Of what is hydrogen one of the constituents? What is oxygen? What first called? Is it heavier than the atmosphere? How much oxygen does the atmosphere contain? What are oxides? Of what fluid is oxygen one of the constituents?

Fig. 6.

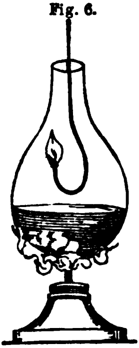
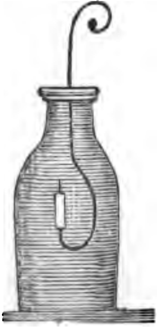


Fig. 7.



is the best supporter of combustion known. Thin iron wire will burn readily in oxygen gas, throwing off most brilliant sparks, called scintillations.

NITROGEN is also a gas. A candle will not burn, nor can any animal live, in it. It is sometimes called *azote*, which means against life. It does not burn when brought in contact with flame. It is lighter than the atmosphere. Although it destroys animal life, the air we breathe contains four-fifths of its bulk of nitrogen. (See Appendix, 5.)

All the gases hitherto described are colorless, and therefore invisible. They are also elastic, which means they can, by great pressure, be compressed into smaller bulk, but as soon as the pressure

Questions. — What is nitrogen? Can animals live in it? What was its old name? What did it mean? Will nitrogen burn? How much nitrogen does the atmosphere contain? Why are the gases described invisible? Are they elastic? What is the effect of pressure upon them?

is removed, they resume their original volume. The Germans first called these elements gases, which meant *ghosts*, because they could not be seen; they were once supposed to be the soul or spirit of solid matter.

A great many vegetable substances do not contain all the four elementary bodies named and described, but only three of them, namely, carbon, hydrogen and oxygen; all the bodies which contain no nitrogen are called non-azotized substances.

Starch, sugar, gum, woody fibre, oils and fats, are among the most common of the non-azotized bodies, or those which contain only carbon, hydrogen and oxygen. Substances which contain nitrogen are called azotized.

Eight or ten different substances are found in the inorganic part of plants: these are potash, soda, lime, magnesia, oxide of iron, oxide of

Questions.—What do the gases do if the pressure is removed? Are all the four preceding elements found in vegetable substances? Which is not found in a great many? Name some of the most common in which nitrogen is not found. What are those called which contain no nitrogen? What those which contain nitrogen? How many substances are found in the inorganic part of plants? Name them.

manganese, silicia, chlorine, sulphuric acid and phosphoric acid. (See Appendix, 6.)

POTASH, as commonly found, is called a salt. Its base is a metal called potassium. The potash, as found in the shops, is obtained from wood-ashes, by boiling them in water, straining, and then boiling down to dryness. Potash is thus procured by leaching wood-ashes, to which any kind of fat is added, the mixture is boiled, and it becomes soft-soap. Potash is an alkali; it absorbs moisture from the air, and soon turns to a liquid. Its metallic base, potassium, attracts oxygen from water when thrown upon it, and takes fire as it floats on the surface of the water. (See Appendix, 7.)

SODA is also an alkali; it is made from sea salt. Its base is a metal called sodium. As we buy it in the shops, it looks like pieces of coarse glass; these pieces are called crystals. If exposed to the air, it soon dries and crumbles into

Questions. — What is potash? How is potash obtained? What is its base called? Boiled with fat, what does it make? What is potash called? How does the air act upon it? How does potassium act if thrown on water? What is soda? What is it made from? What is its base called? What do its crystals look like? What does it do in the air?

a fine white powder. Boiled with fats, or oil, it makes hard soap. (See Appendix, 8.)

LIME is a well-known substance. It looks like pieces of white earth. It is an alkali. Lime-stone is burned in a kiln, and it is then called quick-lime. When water is poüred on quick-lime, it *slakes*, becoming very hot, and throwing off a great deal of steam. Slaked lime is in the form of a white powder. It is used in making mortar, which is a mixture of slaked lime and sand. It has also a metallic base, which is called calcium. Chalk, marble and spar, are lime combined with other bodies, called acids. Bones contain much lime, and so do oyster and other shells. When bones and shells are burned in a hot fire, their organic part is consumed, and the inorganic part, or lime, remains in the fire. Egg-shells are almost all lime. If fowls cannot get lime, or something which contains lime, their eggs are soft, and have no shell. Lime is one of the most abundant things the earth contains. (See Appendix, 9.)

Questions.—Boiled with fats, or oil, what does soda make? What does quick-lime look like? How is it made? What effect has water poured on lime? Name some of the varieties of lime. What is lime found in? Is lime very abundant?

MAGNESIA.—You have seen the magnesia sold by the druggists, or in the shops. It is in lumps, very white and powdery. In that state it is called carbonate of magnesia. It has a metallic base, called magnesium. When carbonate of magnesia is burned where the air cannot get at it, it is called calcined magnesia. There is a kind of limestone called *Magnesian*, from which magnesia is procured. It is also obtained from sea-water. Magnesia is a very mild alkali. All the alkalies, when mixed with acids, combine with them, and make what are called salts. In the act of uniting, the mixture froths up, and looks as though it was boiling. This boiling up and frothing is called *effervescence.*

IRON is a well-known metal. It is the most useful of all the metals. It is found in the earth, and is called iron ore. Iron is obtained by smelting the ore in large and very hot furnaces. Steel is iron combined with carbon. Iron is a soft metal, steel is very hard. Iron is ductile,

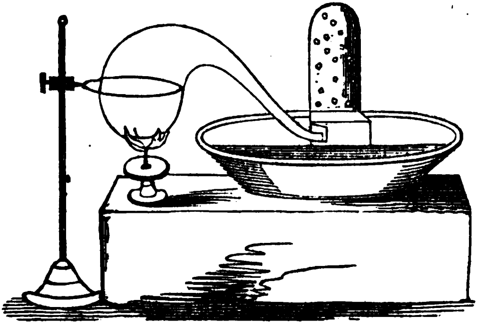
Questions. — What do you know about magnesia? What is calcined magnesia? What is it obtained from? What is its metallic base called? What do the alkalies do when mixed with acids? What is the frothing up called? Can you tell me anything about iron? Where is iron found? How is it obtained?

which means that it can be drawn out very fine; and it is malleable,—that is, it can be rolled or hammered out very thin. (See Appendix, 10.)

OXIDE OF IRON.—If iron is exposed to the atmosphere, it becomes, after a while, covered with a reddish-brown powder, or rust; this rust is oxide of iron; the iron has attracted a portion of oxygen from the atmosphere, and combined with it. Metals will not oxidize in a dry place, or protected from moisture. (See Appendix, 11.)

Sometimes the oxide of manganese, a substance very much like the oxide of iron, is found

Fig. 8.



Questions. **—What is the rust of iron? Will metals oxidise in a dry air? What oxide, much like iron, is sometimes found in soils and plants?**

in soils and plants; but it is usually, when found at all, only in very small quantities.

SILICIA is the name by which the chemist designates the several varieties of flint, rock-crystal, sand-stone, etc.

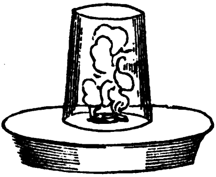
CHLORINE is a gas having a strong, suffocating smell, and a greenish-yellow color. It is twice and a half heavier than the atmosphere. A taper burns in it with a dull, smoky flame. It takes the color out of almost all vegetable substances; hence it is sometimes called the bleaching gas. One hundred pounds of common salt contain sixty pounds of chlorine. [See Appendix, 12.]

SULPHURIC ACID is often called oil of vitriol, but the first is its proper name. It is made by burning brimstone and saltpetre in leaden chambers, containing water on their floors. It is exceedingly sour, and decomposes vegetable or animal substances when poured upon them. Sulphuric acid is found in gypsum, alum, Epsom salts, and many other substances. Combined

Questions. — What is silicia? What is chlorine? Is it heavier than the atmosphere? How much heavier? How does a taper burn in it? Why is it called the bleaching gas? How much chlorine is there in one hundred pounds of common salt? What is sulphuric acid often called? How is it made? What effect has it on organic substances? In what is it found?

with alkalies, it forms salts. It is so acrid that it burns or destroys wherever it drops upon organic substances. It is composed of sulphur and oxygen. Combining with water, it gives out a very intense heat, often breaking the vessel in which the mixture is incautiously made. [See Appendix, 13.]

Fig. 9.



PHOSPHORIC ACID is oxygen combined with phosphorus. Phosphorus is so very inflammable that it can only be handled with the greatest care. It is slowly consumed in the air, emitting white fumes; these fumes are phosphoric acid. You may learn its smell from a lucifer-match, if you just rub it, without setting it on fire. Phosphorus exists, in large quantities, in the bones of animals, and it is prepared in very great quantities for the use of match-makers. [See Appendix, 14.]

All these substances, in different proportions,

Questions.—What does it make with alkalies? Of what is it composed? What is phosphoric acid? Is phosphorus very inflammable? How should it be handled? How may you learn its smell? In what is it abundantly found?

are found in the inorganic part, or ashes, of our commonly cultivated plants. But some plants yield a much larger quantity of ashes than others. One hundred pounds of dry hay will yield, after burning, from eight to ten pounds of ashes; but the same weight of wheat will only give between one and two pounds of ashes.

The proportions in which these substances are found in the ashes of different plants differs very much. The ashes of hay contain much more lime than the ashes of wheat,—and the wheat-ash contains more phosphoric acid than the hay.

These facts are of the greatest practical importance to the farmer, as we shall soon be able to show our young friends; and many lands have been ruined because the farmer neither knew the nature of his soil nor the food his crops consumed.

THE FOOD OF PLANTS.

Plants require constant supplies of food, to enable them to live and grow; without suitable and abundant food, they soon die.

Questions.—Are all the substances described found in the ashes of plants? Do all plants leave the same weight of ashes when burned? Do the ashes of different plants differ *in the proportion* of these constituents? Do plants need food?

Plants obtain their food in part from the air, and in part from the soil: their leaves drink it in from the air, and their roots take it up from the soil. Nor can they thrive alone upon one kind of food: they must have two distinct kinds of food; they must have *organic* food to support their organic part, and *inorganic* food to strengthen their inorganic part. Their organic food is derived from the air and the soil; their inorganic food is obtained from the soil alone.

Fig. 10.

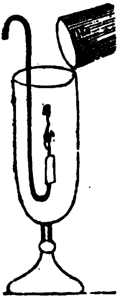
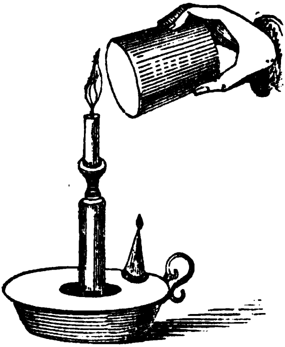


Fig. 11.



Questions.—Where do plants obtain food? How do they obtain it? How many kinds of food do they need? Where do they get their organic food? Where their inorganic food?

Carbonic acid gas is the form of food they mainly derive from the air. This gas has no color, but it has a peculiar smell. It is so heavy that it can be poured from vessel to vessel, like water. It extinguishes burning bodies, and destroys animal life when breathed. It causes the sparkling of soda-water and the frothing of beer, and forms nearly half the weight of all limestone rocks. Animals throw carbonic acid gas out in breathing, and plants drink it in. (See Appendix, 15.)

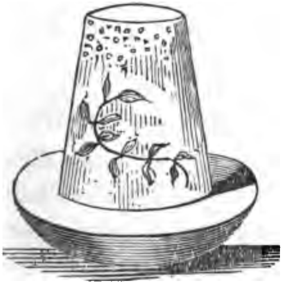
The quantity of carbonic acid gas in the atmosphere is very small, only about two gallons in five thousand; the air we breathe is almost wholly oxygen and nitrogen: in five gallons of the atmospheric air, there are four gallons of nitrogen and one of oxygen. Although the atmosphere contains only the comparatively small quantity of carbonic acid named, yet plants drink it in freely, from the abundance of their leaves, which contain a great number of small

Questions. — **In what form do plants take food from the air? What is carbonic acid gas? Describe some of its properties. Is there much carbonic acid in the atmosphere? In what proportion is it found? How do plants obtain the** ***carbonic acid*** ***from*** **the air?**

openings, or mouths, spread all over their surface, but especially on their under side. Plants take in carbonic acid only during the day; during the night they give it off.

Twenty-two pounds of carbonic acid gas contain six pounds of carbon and sixteen of oxygen; and this is readily proved by burning charcoal in oxygen. (See Appendix, 16.)

Fig. 12.



Plants only retain the carbon contained in the carbonic acid; they give the oxygen back again to the air. We can prove this very easily. Fill a tumbler with clear water; put into it a few fresh green leaves; then invert the tumbler in a saucer, so that it shall remain full. Place it in the sun, and bubbles of oxygen may be seen arising from the leaves, occupying the upper part of the tumbler.

Questions.—Do the leaves take in carbonic acid all the time? Of what is carbonic acid composed? Can you prove this? Do plants retain all the carbonic acid? How can you prove they give back the oxygen?

Besides carbonic acid gas, the leaves of plants drink in watery vapor from the atmosphere, which moistens the leaves and stems, and at the same time adds to the substance of the plant.

Plants take up carbon from the soil in the form of carbonic acid, humic acid, and some other combinations in which it exists in the vegetable matters of the soil (see Appendix, 17); and they obtain nitrogen from the soil in the forms of ammonia and nitric acid, which we shall before long describe to our young friends.

SUBSTANCES IN THE STRUCTURE OF PLANTS.

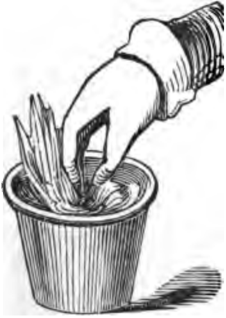
Plants are mainly made up of woody fibre, starch, and gluten. The woody fibre constitutes the greater part of every kind of wood, straw, hay, chaff, cotton, flax, hemp, the shells of nuts, etc.

Starch is first seen in the form of a white powder. Nearly the whole substance of the potato is starch, and nearly half the weight of

Questions. — Do plants drink anything from the atmosphere besides carbonic acid? What use do they make of water? How do they take up carbon from the soil? Whence do they obtain nitrogen? What substances enter into the *structure of plants?* What does the woody fibre form? *What is starch?*

oat-meal, the flour of wheat, and of all other grains cultivated for food.

Fig. 13.



Gluten is a sticky, tenacious substance, found along with the starch, in almost all plants. It may be easily obtained from wheat-flour, by making it into a dough, and then repeatedly washing it with water. (See Appendix, 18.)

In the stems of plants the woody fibre is the most abundant, and starch is most abundant in their seeds: starch is also very abundant in the potato, and other roots of a similar kind.

Woody fibre, starch, gum and sugar, all consist of carbon and water only; and, as water contains hydrogen and oxygen, the articles just named consist of carbon, hydrogen and oxygen.

Questions.—What is gluten? How may gluten be obtained? Which of the substances named is most abundant in the stems of plants? Which in the seeds? Does starch exist in the roots of plants? Of what do woody fibre, starch, gum and sugar, consist?

Now, if you remember that plants drink in carbonic acid and water, you will see that they can form all these very unlike substances therefrom; and, as the leaves require only carbon and water to form the woody fibre and starch of which they are composed, they give off the oxygen of the carbonic acid because they cannot make any use of it. (See Appendix, 19.)

Notwithstanding plants drink in so much carbonic acid from the air, they can never exhaust it, because new supplies are being continually thrown into it from other sources, which are three in number:—

1. From the breathing of animals; for all animals throw a small portion of carbonic acid into the air, every time they breathe.

2. From the combustion of wood, coal, candles, oil, etc.; for all these things contain carbon, which, as they burn in the air, form carbonic acid, as the charcoal did when burned in oxygen.

3. From the decay of vegetables and roots; for decay is only a slow kind of combustion,

Questions. — Can all these be formed from the food the leaves drink in? Why do the leaves give out the oxygen of the carbonic acid? Why do not plants exhaust the air of all its carbonic acid? From whence does the air obtain *carbonic acid?*

whereby the carbon of plants is changed into carbonic acid.

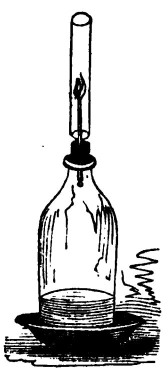
Thus it is seen how wisely Infinite Wisdom has adapted every fact in nature to some purpose of good. Animals produce and throw off carbonic acid and water, and plants take in and live upon the carbon thus thrown off. Having drank in the carbonic acid by its numberless mouths, the plant transforms it and water into starch, sugar, etc., upon which animals live.

The fibre of wood, starch, sugar and gum, contain carbon and water only; water is only oxygen and hydrogen. Nine pounds of water contain about eight pounds of oxygen and one pound of hydrogen. Water, as you know, extinguishes fire; and yet it is composed of two gases, one of which, the hydrogen, burns very readily, and in the other, the oxygen, bodies burn with increased brilliancy. This fact appears wonderful, but there are many other substances whose composition is equally astonishing. *White* starch consists of *black* charcoal and

Questions.— By whom is carbonic gas thrown out? What do plants do with the carbon thrown off by animals? What does water consist of? In about what proportions? Of what does starch consist?

water only, and sugar and gum contain exactly the same elements as starch and the fibre of wood. Now, as water contains hydrogen and oxygen, the substances which consist of carbon and water really contain carbon, hydrogen and oxygen. (See Appendix, 20.)

Fig. 14.



That water really contains only hydrogen and oxygen gases, may be very easily proved by burning hydrogen in oxygen. Put into the bottle (Fig. 14) a few old nails, or clippings of zinc, and pour upon them sulphuric acid diluted with four or five times its measure of water. Hydrogen gas will thus be formed rapidly. Having put the stem of a tobacco-pipe through a cork, the size of the neck of the bottle, close it therewith. The gas will soon rise through the pipe. When the gas has escaped a few minutes, the jet may be lighted from a match.

Questions.— Can you tell me any other substances which contain only carbon and water? What do those substances which contain only carbon and water really consist of? How can you show that water contains only hydrogen and *oxygen?*

Then take a dry glass tube, from ten to twenty inches long, and about one inch in diameter, and pass it over the jet, as in the cut. A musical sound will be heard issuing from the tube, which will soon become moist on the inside. If a tube is not to be had, a dry tumbler may be used, and the water produced will be condensed inside it. Now, whence came the water? The hydrogen gas, in burning, united with just sufficient of the oxygen contained in the air to make water.

Gluten, unlike the substances already described, contains four elements; it contains nitrogen, in addition to carbon, hydrogen and oxygen. The nitrogen which plants require, to make gluten, is obtained almost wholly from the soil.

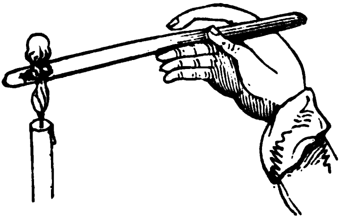
OF THE SUBSTANCES WHICH FORM SOIL.

The soil contains two kinds of matter,—organic, or the part which is combustible; and inorganic, or the part which will not burn.

This may be shown by heating a small portion

Questions.— Where does the hydrogen, in burning, get the oxygen necessary to make water? How many elements does gluten contain? Name them. Whence do plants obtain their nitrogen? How many kinds of matter are there in *soil? Name them.*

Fig. 15.



of soil to redness, on a strip of sheet iron (see Fig. 15), over a lamp. The soil first blackens, proving the presence of carbon; and, as the carbonaceous matter burns away, the soil becomes a gray-brown, or reddish color. (See Appendix, 21.)

The organic part is obtained from roots and stems of decayed vegetable and animal matter, and from dung and other manures. In peaty soils, the organic part forms, often, three-quarters of their whole weight; but in rich and fertile land it is not often more than from one-twentieth to one-tenth of their weight.

In our country, soils which do not contain a full proportion of organic matter cannot yield good crops. A rich soil should consist of at

Questions.—How can we prove that soil contains two kinds of matter? Which burns away? Which part is not consumed? Whence does soil obtain its organic matter? What is its quantity in peat lands? What in good soil?

least one-twentieth, or five per cent., of organic matter.

If land is ploughed and planted year after year, and but little manured, the organic matter is exhausted, and the crops are poor; but when the soil is put to permanent pasture, or sufficiently enriched with farm-yard or other appropriate manure, as peat, compost, or guano, it is not impoverished, because the crops do not exhaust it of its organic matter.

The quantity of organic matter plants take up from the soil differs greatly, depending on the kind of land, the nature of the plant, and the season; but they always take up a good deal, and it is essential for the health and perfection of the plant.

The requisite supply of organic matter in the soil may be insured by ploughing in green crops, by sowing clover, and the grasses, which leave abundant roots in the soil, and by restoring the

Questions. **— How much organic matter should land contain, to produce good crops? What impoverishes land? How can it be kept from being exhausted by crops? Do all plants take the same quantity of organic matter from the soil? Why do they thus differ? Why is organic matter essential for the plant? How may the requisite supply of organic matter be retained in the land?**

woody fibre of vegetables, as hay, straw, cornstalks, etc., in the form of manure.

The inorganic or incombustible part of the soil is derived from the gradual crumbling down of different kinds of rocks. The decaying walls of buildings, the substance called *rotten rock*,—which is trap or whinstone in a decomposed state,—limestone, gravel, etc., are also sources which supply inorganic matter to the soil.

Rocks consist, to a large extent, of sandstones, limestones, and clays. Of the sandstones, there are the red, and the white, and other freestones. Limestones include chalk, gypsum, the blue, and other varieties. Clays comprise the slate used for roofing, and the shale or shiver of the coal beds. All the inorganic part of soils mainly consists of sand, clay, and lime.

Sometimes soil contains one of these substances in a much larger quantity than either of the others. When sand is most abundant, the land is called sandy soil. If the clay greatly predominates, it is a stiff, or clay soil. If the lime

Questions.—Whence does the soil derive its inorganic part? Of what do rocks chiefly consist? Name some of the varieties of sandstones. Of limestones. Of clays. When soil contains most sand, what is it called? What, *when clay is most abundant?*

is in the greatest quantity, it is a *calcareous* soil. The word *calcareous* is made from the Latin word *calx*, which means lime; therefore, a *calcareous* soil is one that contains a great deal of lime.

Sand and clay, with only a moderate quantity of lime, is called a loam; if the lime is more abundant, it is then a calcareous loam; if the clay is in large quantity, with an abundance of lime, it is a calcareous clay.

When lands contain a large quantity of sand or gravel, they are called light lands; when the soil contains a large proportion of clay, it is then known as heavy land.

The light lands are most easily cultivated, and they are often called barley or turnip soils, because they are best fitted for barley, turnips, or green crops.

Both light and heavy lands require draining. Clay land retains the most water, and it often is seen on the surface of the soil. But sandy soils,

Questions. — What is soil called when lime is in greatest quantity? What is the meaning of calcareous? What is loam? What is a calcareous loam? What is a calcareous clay? What are light lands? What are heavy lands? What crops are best fitted for light soils? What lands require draining? What difference is there in light and heavy lands as regards water?

although generally dry on the surface, are often so wet below as to require drains to carry off the excess of water.

A drain should seldom be less than thirty inches deep; because the deeper the soil is made dry, the deeper the roots of plants will descend in search of food. If the drains are as deep as thirty inches, the soil can be turned up with the subsoil plough to the depth of nearly two feet, without running the risk of injuring them.

Draining is beneficial to the land for other reasons. Drains admit air to the subsoil, and they allow the rain to sink down and wash out of it many substances which would be injurious to the crops. It is not uncommon for crops, which at first look very promising, to droop and fail when their roots reach the injurious substances in the subsoil.

Heavy or clay lands are often let stand as permanent pasture, because the labor and expense of ploughing and working them is so great, that the crops of grain obtained from them do not re-

Questions. — How deep should drains be? Why? Do you know any other reason for deep drains? Of what other advantage is draining? Are crops ever injured by the *substances* contained in the subsoil of undrained lands? *Why are clay* lands often let stand in pasture?

turn to the farmer a sufficient compensation. But these lands could be made lighter, more easily cultivated, and yield very productive crops, if they were drained, subsoil ploughed, and lime or marl added as required. When thus improved, their yield of grain will be increased by, sometimes, scores of bushels to the acre; and the cost of draining and improving is usually paid back to the farmer in three or four years, from the largely increased yield and more profitable nature of the crops.

THE INORGANIC FOOD OF PLANTS.

The inorganic, or earthy part of soil, answers a double purpose: *first*, it keeps the plants in a firm and upright position, because their roots are securely held therein: and *second*, it furnishes the plant with that food which it requires for the perfection and growth of its inorganic parts.

In addition to the sand, clay and lime, of which the inorganic part of soils mainly consists, they also contain small amounts of potash, soda,

Questions.—How could clay land be made more profitable? Do draining and other improvements pay the farmer for their cost? Of what use is the inorganic part of the soil? What substances does the soil contain besides sand, clay, and *lime?*

magnesia oxide of iron, oxide of manganese, sulphuric acid, phosphoric acid, and chlorine. These substances are found, in different proportions, in the ashes or inorganic part of all plants, and the plants derive them solely from the soil, as none of them are found in the air.

Plants take up these inorganic substances through their roots; but before they can do so they must be dissolved, or made into a solution, by the rain water, or the waters of springs. So long as they remain solid, or undissolved, they are valueless to the plant, which can derive no food from them. (See Appendix, 22.)

All fertile or productive soils must contain these inorganic substances; because without them plants must languish, and the crops be poor and unproductive.

All plants do not require the same quantity of all these substances; some take up a large quantity of one or more of them, and only a very small portion of the others. (See Appendix, 23.)

Questions. — Where are the last-named substances found, besides in the soil? Do plants take them up? How do they take them up? In what form do they take them up? Must *fertile* soils possess these inorganic substances? Why? Do *all plants require* the same proportion of these substances?

The following table shows the quantity of ashes left after burning one thousand pounds of hay, made from the different grasses named, and the composition of the ashes of the several kinds of grass. (See Appendix, 23.)

Inorganic Substances.	Rye Grass.	Red Clover.	White Clover.	Lucerne
Potash,	9	20	31	18½
Soda,	4	5¼	6	6
Lime,	7	28	23½	48
Magnesia,	1	8	3	3½
Oxide of Iron,	trace	trace	½	⅛
Silicia,	28	4	15	8½
Sulphuric Acid,	8⅔	4½	3½	4
Phosphoric Acid,	¼	6½	5	13
Chlorine,	trace	3½	2	3
	53	74¾	80½	94⅔

Now, you will see that unless the soil contains all the substances found in the ashes of plants, the plants cannot grow perfectly; and, although some of those substances are only found in very small quantities in the plant, yet their presence is necessary for its health and life.

Questions.—What does the table show? How many pounds of ashes in one thousand pounds of rye grass? In red clover? In white clover? In lucerne? Are substances, found only in very small quantity in the plant, *necessary in the soil?*

If a soil was wholly destitute of one of these substances, it could not yield good crops; and if it contained an abundance of them all, with but a single exception, and that found only in a very small amount, plants which required only a very small quantity of that substance would thrive well on such soil; but those which required a large quantity of that substance of which the soil contained only very little, would be stunted, unhealthy, and unproductive.

Suppose a piece of land contained only a small quantity of lime, you will find, on looking at the table of ashes, that rye grass, which contains very little lime, would do well on that soil; but lucerne, which contains a great deal of lime, would not be likely to thrive on land which contains only a small quantity of that substance. Rye grass would grow well on soil containing an abundance of sand, but lucerne would not so well. Rye grass requires very little phosphoric acid in the soil; lucerne requires a much larger quantity.

Questions. — What would be the result of a soil containing none of some one of these substances? What would be the result of soil containing plenty of all these substances, *with only* a small quantity of some one of them? Give an *illustration of the fact* just named.

If in any soil most of these inorganic substances were absent, it would be naturally barren, and no good or productive crops of any kind could be raised from it. There are many large tracts of land, in all countries, which have never been under cultivation, that are naturally fertile and productive, and many other tracts which are naturally barren and unproductive.

In naturally fertile soils all those inorganic substances are found which are required by our cultivated crops for food; in barren soils some of these substances are wholly wanting.

	Fertile without manure	Fertile with manure	Barren
Organic matter,	97	50	40
Silicia (in the sand and clay),	648	833	778
Alumina (in the clay),	57	51	91
Lime,	59	18	4
Magnesia,	8½	8	1
Oxide of iron,	61	30	81
Oxide of manganese,	1	3	½
Potash,	2	trace	trace
Soda, } chiefly as com. salt,	4		
Chlorine, } chiefly as com. salt,	2		
Sulphuric acid,	2	¾	
Phosphoric acid,	4½	1¾	
Carbonic acid, comb. with lime and magnesia,	40	4½	
Loss,	14		4½
Parts,	1000	1000	1000

The above table shows the composition of

Questions.—What makes soil barren? What is the difference between naturally fertile and naturally barren soils?

soils naturally fertile, artificially fertilized, and barren:—

The soil whose composition is found in the first column of the table had yielded good crops for sixty years without manure, and yet contained an appreciable amount of all the inorganic substances required by plants. The soil described in the second column produced good annual crops by the addition of appropriate manures; it was deficient of three or four substances, which were supplied by the manures. The third was irrecoverably barren; it was deficient of substances which none of the ordinary manures could supply.

Notwithstanding a soil containing the inorganic substances required by plants as food, it may be still unproductive or barren, by the presence of some one largely in excess. The oxide of iron, when present in a very large amount in soil otherwise good, would render it incapable of producing good crops.

To remedy this evil, the land should be thorough drained and subsoiled, so that the rains might easily penetrate it and wash out the inju-

Questions.—What will cause a soil, in other respects good, *to be unproductive?* How may that defect be overcome?

rious substance, and this result would often be aided by supplying an additional quantity of lime.

Good and fertile land will soon become poor and unproductive, if the same kind of crops are raised on it year after year. If wheat or oats be raised season after season from the same soil, it will after a while be unable to produce a good crop of either of these grains.

The reason why a succession of crops of the same kind will impoverish good land, and make it unproductive, is easily seen. They take up from the soil certain substances in large amounts, until, after a while, the soil can no longer furnish the substances required by the plants.

Inorganic Substances.	Wheat.	Oats.	Barley.	Rye.
Potash and Soda, ...	37.72	19.12	20.70	37.21
Lime, ...	1.98	10.41	3.36	2.92
Magnesia, ...	9.60	9.98	10.05	10.13
Oxide of iron, ...	1.36	5.08	1.98	0.82
Oxide of manganese, ...	trace	1.25	trace	trace
Phosphoric acid, ...	49.32	46.26	40.68	47.29
Sulphuric acid, ...	0.17		0.26	1.46
Silicia, ...		3.07	21.99	0.17
Parts, ...	100.00	98.87	98.92	100.00

Questions —What is the effect of continually raising the same crops on a piece of land? Why does a succession of the *same crop* impoverish the soil?

Crops of grain rapidly exhaust the soil of phosphoric acid, magnesia, potash, and soda, as will be seen by looking at the table showing the constituents of the inorganic part, or ash, of wheat, oats, barley, and rye.

Unless phosphoric acid, magnesia, potash, and soda, be constantly supplied in the form of manure, it will be seen that successive crops of grain must soon take up all those substances the soil contained, and thereby render it incapable of producing further crops.

The phosphoric acid may be supplied to the soil by the addition of bone-dust, guano, or other substances containing an abundance of phosphorus. Common salt will supply soda and a little magnesia, and wood-ashes will give some potash. Bones also furnish lime to the soil, a substance which oats require in pretty large quantity.

If the crops raised are always carried away from the soil, and their inorganic elements are

Questions.—Of what substances do grain crops most rapidly rob the soil? How may the impoverishment of the soil be prevented? What substances will yield phosphorus to the soil? How may soda, magnesia, and potash, be supplied? Do bones supply anything besides phosphorus?

not artificially supplied, the best land will soon become poor. Each crop robs the soil of a certain quantity of its substance; and, of course, if the farmer annually takes away these substances from his land in his crops, and never makes good the loss by new additions, he must expect his farm soon to be *run out.*

By the addition of manures containing the substances the crop takes from the soil, its productiveness may be made permanent. Manures should be supplied of the right kind, in appropriate quantities, and at the proper periods of the year; and there should always be more in quantity of the substances taken up by the crops, than they annually consume.

Many farmers are afraid of the cost of manures, and so they always have unproductive land and unprofitable crops. Others supply an abundance of manure, but it often is not the kind the land needs, and is just so much waste; whilst others render the manure they do use of

Questions. — Why does the removal of crops from the land impoverish it? How may the productiveness of land be maintained? What kind of manures should be used? Should the manures contain more of a given substance than the crop consumes?

but little value, by their careless mode of preparing or keeping it.

ON THE APPLICATION OF MANURES TO THE SOIL.

Everything that supplies food to plants through the soil may be called a manure. There are three distinctive kinds of manures: vegetable, animal, and mineral. Vegetable manures are those parts of plants that are buried in the soil, which they enrich by the process of decomposition or rotting, whereby the substances of which they are composed are returned to the land. Grass, clover, straw, hay, potato-tops, cornstalks, etc., are amongst the most valuable of the vegetable manures. Sometimes a crop of green grass is used as a manure, by being ploughed into the soil. When grass is to be ploughed up for manure, the sods should not be deeply buried; they should be left so near

No. 16.

Questions. — What is a manure? How many kinds of manure are there? Of what do vegetable manures consist? *Should* green crops be deeply ploughed in for manures?

the surface that the roots of the young grain may be enabled to feed upon the decaying grass. Clover, buckwheat, rape, rye, and sometimes young turnips, are ploughed in green, as manure.

Green crops should be ploughed into light and sandy soils, and such as are poor in vegetable matter. Sea-weed is also a very valuable manure, adding largely to the richness of the soil. It not only supplies vegetable matter, but saline substances. It is either spread over the land, where it rots, or it is first made into a compost. Marl and shell-sand, mixed with sea-weed, and turned over twice or thrice before application, makes a very excellent compost for light soils. Potato and turnip tops, when the roots are dug, make a good manure if ploughed in, especially if grain is to be the next crop. By pulling off the blossoms from the potato-stalks, they may be kept green until the potatoes are dug out, and thus the yield of green manure is much increased.

Questions.—Why should the sods be left near the surface? Name other green crops which are ploughed in as manures. For what kind of lands are green crops the best manure? Is sea-weed a good manure? How may the quantity of potato-tops be increased for manure?

Hay is returned to the land in the form of the dung of the animals by which it has been used as food. Straw is sometimes cut and mixed in feed, and thus becomes manure; but it is generally returned to the soil trodden amongst the litter. Where few cattle are kept, straw is rotted with water and a little cow-dung, and put into the land in a half-fermented state. For light lands, the straw, etc., should be well rotted; but for heavy lands the manures are best applied half-fermented, because then they help to keep the soil light and porous.

Rape-cake and rape-dust are also applied as manures to turnips and potatoes, thereby saving the whole or a part of the common farm-dung. It is also sometimes applied advantageously as a top-dressing to spring wheat. Rape-cake is the substance that remains when the oil is squeezed out of the seed; and when the cake is dried and crushed it becomes rape-dust.

The most important animal manures are blood,

Questions.—How is hay returned to the soil as a manure? How is straw used for the same purpose? What difference should there be in vegetable manures for light and heavy soils? Is rape-cake useful as a manure? How is it made? How is it applied as a manure?

flesh, bones, hair, wool, and the dung and urine of animals. Many kinds of fish are also much used as a manure.

Blood, as a manure, is best mixed with the general refuse of the manure-heap. It is sometimes dried, and applied as a top-dressing, or drilled in with the seed. It is one of the most powerful fertilizers.

The flesh of dead horses, diseased cows, hogs, etc., and dogs, when decomposed, makes a very valuable manure. They should be buried in soil to which saw-dust or marl is added, or be decomposed by the action of oil of vitriol. Sometimes lime may be advantageously added to the substances to undergo decomposition, whereby all the gases disengaged during that process are absorbed and retained for use.

Bones are broken and crushed in suitable mills, and sifted into various degrees of fineness, from a coarse dust into pieces of half-inch or inch in size. Bones act most quickly as a fertilizer

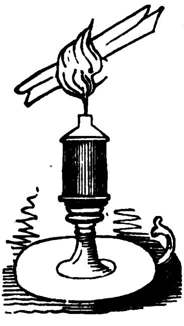
Questions. — What are the most important animal manures? How is blood applied as a fertilizer? How is flesh best prepared for manure? How are bones prepared as a fertilizer? How do bones act most quickly as a manure?

when reduced into powder; but they are sooner exhausted than when used in a larger form.

Bones are best adapted for light or well-drained lands, and may take the place of the whole or part of the farm-yard manure. When they are so used, it is well to combine them with wood-ashes, and, thus mixed, they may be drilled in with turnip or other seed.

Crops of turnips do best when manured, alternate seasons, with bones and the compost of the farm-yard.

Fig. 17.



Bone-dust may be profitably applied, as a manure, to grass lands that have been long pastured by growing stock; nor is the wetness of the soil an objection to their use.

Bones consist of a peculiar earth, the phosphate of lime, and glue, or gelatine. If you burn a thin piece of bone in

Questions. — For what lands are bones best adapted for manure? How may they be used? How do turnips thrive best? To what other purpose may bone manure be applied? *Of what are bones composed?*

the flame of a lamp, the organic part, or the gelatine, is consumed, and the inorganic part, or the phosphate of lime, remains unburned. The gelatine may be also to a large extent removed by boiling in successive portions of water. By boiling under a pressure of steam, all the gelatine may be dissolved out.

The glue or gelatine of bones is a very good and powerful manure; and materially assists in advancing the growth of the turnip crop.

The bone-earth, or the part left unconsumed by fire, contains phosphoric acid and lime. The phosphorus and lime are both valuable manures, as may be seen on reference to the table, page 47, which shows how much of these substances some crops annually take from the land.

Bones are essentially requisite on old dairy lands. Milk and cheese both contain bone-earth; and, unless the soil is replenished with phosphoric acid and lime, it soon becomes poor and unproductive, or only capable of growing grasses

Questions.—If you burn a bone, what is consumed? What remains unconsumed? What is the effect of the glue or gelatine of bones? Of what is bone-earth composed? Are they valuable manures? Why are bones requisite on old dairy lands?

which require a small quantity of those substances.

In every ten gallons of milk there is about half a pound of bone-earth; hence a cow which gives twenty quarts a day takes from the soil about two pounds of phosphate of lime every week. To restore these two pounds of phosphoric acid and lime to the soil, three pounds of bone-dust are required; and, by the process of decomposition, the land obtains the phosphoric acid and lime of which the inorganic part of the bones was made.

For manure, bones are sometimes dissolved in sulphuric acid; and, for this purpose, equal weights of bone-dust and acid are mixed together, and allowed to stand until the acid has chemically decomposed the substance of the bones.

By thus preparing the bones for manure, the substances of which they are composed are very minutely divided; they are, on this account,

Questions.—How much bone-earth in every ten gallons of milk? How much bone-earth is taken from the soil every week by a cow giving twenty quarts of milk a day? How much bone-dust is required to make good to the soil what it thus loses? Are bones applied as manure in any other form? What is the advantage of thus preparing the *bones?*

more readily taken up by the roots of the plants, because the acid has already done what must otherwise have been effected in the soil; for, until the bones are decomposed, they are of no value as a manure. Another advantage is, a smaller quantity produces an equal effect on the crop.

Sometimes another mode is adopted. A given weight of bone-dust and an equal weight of sulphuric acid are mixed, and to this thirty times the bulk of water is added. This mixture may be applied to the soil from a common watering-cart; or sufficient powdered charcoal, peat, saw-dust or soil, may be added to take up all the fluid, when the compost may be applied in the usual way. The charcoal is a good addition; but the peat and the saw-dust are gradually converted into carbon.

Hair is not much used as a manure, because of its expense. The sweepings of our hair-cutters' rooms, now all wasted, might be collected and most profitably used.

Questions. — Is there any other mode of preparing bones for manure? Describe how this preparation may be applied. May this mixture be made into solid compost? How? *Is hair* much used as a manure? Is not much hair *wasted?*

Woollen rags, cut into small pieces and mixed with earth, make a very useful compost; and they are much more effective if first decomposed by sulphuric acid.

The contents of privies, and the dung of horses, cows, sheep. pigs, and birds, are all employed as manures. Night-soil, now manufactured into an article called *poudrette*, and birds' dung (guano), are the most valuable as fertilizers: next, pigs' dung, and lastly that of cows.

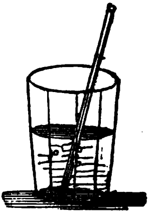
Night-soil is most valuable as a manure, because men live upon a mixed animal and vegetable diet, whereby their excrement is richer in those substances which plants take up from the soil. The dung of horses is more valuable than that of cows, because the horse makes comparatively little water. Pigs' dung is by some thought objectionable, as it has been supposed to give a disagreeable taste and smell to crops raised from it; an opinion, we think, without

Questions.—How are woollen rags best used a manure? Name some other sources of manures. What is manufactured night-soil called? What is guano? Why is night-soil most valuable as a manure? Why is horse dung a better fertilizer than that of cows? Why has pig dung been deemed objectionable?

foundation. It is always better mixed into a compost with other manures than used alone.

Cow dung is colder, and less easily decomposed, because, by the large quantity of urine voided by the cow, most of the excrementitious salts are carried away. This defect may be remedied by the addition of wood-ashes, or quicklime, well turned into the heap, whereby the process of decomposition is greatly hastened, and the manure much improved.

Fig. 18.



The mixed dung of animals differs from the food they consume, in containing less carbon and more nitrogen than the food eaten. The carbon is thrown off by the lungs in the act of breathing, in the form of carbonic acid gas. A man throws off from his lungs about half a pound of carbon daily; and a horse or a cow, eight or ten times as much. You may see the carbonic acid, as it is thus thrown off by

Questions.—How is pig-dung best used? Why is cow dung less valuable as a manure? How may it be much improved? Wherein does the dung of animals differ from their food? What becomes of the carbon? How much carbon does a man throw off daily? How much a horse or cow?

the lungs, by a very simple experiment. Put a piece of lime into a pitcher of water, and let it stand a day. Take some of the clear lime-water, put it into a tumbler, and pass the air from the lungs through it, by breathing through a straw or a clean pipe-stem. In a little while, the water, which was clear, becomes milky, and soon carbonate of lime (chalk) falls to the bottom. (See Fig. 18.)

The water contained a clear solution of lime; the lime combined with the carbonic acid in the air breathed from the lungs, and formed the carbonate of lime; and, as that will not dissolve in water, it is visible to the eye, and soon settles on the bottom of the tumbler.

Almost all the nitrogen contained in the food is retained in the excrements of animals, mixed with a smaller quantity of carbon than they took in with their food; and the larger proportion of nitrogen contained in the dung of animals is one of the causes of their greater value as a manure.

The nitrogen, in the process of the decompo-

Questions.—How can you prove that carbonic acid is *thrown out* in the act of breathing? What becomes of the *nitrogen* contained in the food of animals?

sition of manures, is changed into ammonia, which is a kind of air, or gas, having a very strong smell. The hartshorn of the shops is only water holding ammoniacal gas in solution; and smelling-salts owe their pungency to the ammonia they contain.

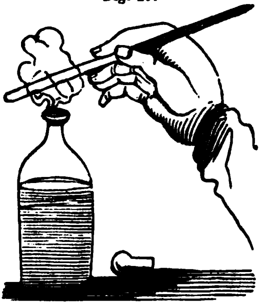
The ammonia is produced by the fermentation of compost or manure heaps, and is the cause of the smell perceived in stables and privies. It is a very valuable agent in manures, and should be kept from flying off by the addition of sulphate of lime, whereby the volatile carbonate of ammonia is transformed into the non-volatile sulphate of ammonia.

You may detect the presence of ammonia by dipping a feather into vinegar and holding it over the dung-heap in the stable, when, if ammonia is forming, it will be seen in white fumes around the feather.

Another method will enable you to see the ammonia. Dip a feather into strong vinegar,

Questions. — **Into what is nitrogen changed by the fermentation of manures? Describe ammonia. What is the cause of the smell of stables and privies? Should the ammonia be retained in the manure? How should it be kept from flying off? How can you detect ammonia?**

Fig. 19.



and hold it over the mouth of a bottle containing hartshorn, or a strong smelling-bottle; the white fumes will be seen, showing that ammonia, as a gas, is escaping. These white fumes are the ammonia (an alkali) combining with the vinegar (acetic acid). The white fumes will be more abundant if a glass rod, dipped into muriatic acid, be used.

Ammonia is composed of two gases, nitrogen and hydrogen. Fourteen pounds of nitrogen and three pounds of hydrogen make seventeen pounds of ammonia.

The ammonia contained in manure is dissolved by the water contained in the soil, and it is then taken up by the roots of the plants. In the plant, it aids in the formation of gluten, and other portions of its substance containing nitrogen.

Questions.—Of what is ammonia composed? In what proportions? How do plants obtain the ammonia from the *soil? Of* what use is ammonia in the plant?

Thus you see ammonia is a very important article in the composition of manures; for the growth of the plant demands nitrogen, which it must obtain from the soil.

Ammonia exists in the largest quantity in the urine of animals, especially in that of the cow; and it is hence of importance that it should be preserved, as far as possible. The more liquid portions of all manures should also be saved, instead of being allowed to run to waste, or to soak into the ground of the farm-yard.

Every farmer should have a cemented tank, or a large wooden vat or cistern, in some convenient spot in the farm-yard, into which these liquid manures may collect; and they should be frequently pumped or bailed back upon the heaps of manure or compost, thereby aiding their fermentation, and making them more efficient as fertilizers. A run should connect the dung-heap or compost-bed with the tank, so that the soluble portions of the manure carried off by rains may be again collected.

Questions.—Why is ammonia important in manures? Where is the largest quantity of ammonia found? Ought these fluids to be saved? How can the farmer save them? Of what use are they thrown on manure-heaps?

Another great advantage of the tank is, that during the spring and summer months its contents, after fermentation, and diluted with once or twice its bulk of water, may be applied, by the watering-cart, to grass land, young clover, or any other young crops.

The ammoniacal liquor of the gas-works, diluted with four or five times its bulk of water, may be, where attainable, employed in the same manner and for the same purposes as the liquid manure of the farm-yard; or, it may be made into a compost with peat and vegetable matter.

The excrement of birds is a most valuable manure. The article now so popular, and known as guano, is the excrement of sea-fowls, which has been accumulating for ages in the localities where it is found. Farmers should carefully collect and preserve for use the dung of hen-houses and pigeon-cotes; they make a very efficient top-dressing for young grain crops, and may be used, wholly or in part, in place of the

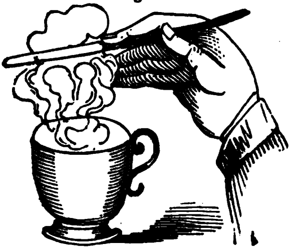
Questions.—Has the tank any other advantage? To what purposes may the ammoniacal liquor of gas-works be applied? What is guano? Is the excrement of other birds *useful as a manure*?

farm-yard manure; they contain a large quantity of ammonia.

These manures should not come into immediate contact with the seed, but should be well mixed with a suitable quantity of earth.

Quick-lime should never be mixed with guano, or other manures containing ammonia; because the lime sets the ammonia free, and allows it to escape into the atmosphere.

Fig. 20.



You may easily be satisfied of this fact. Take a little slaked lime, and mix it with a small quantity of guano, or the excrement of pigeons, etc., in a tea-cup. The ammonia will be at once recognized by its peculiar smell; and you may see it by holding over the cup a

Questions.—What does the excrement of birds contain in large quantity? Should they be applied directly to the seed? Why should not lime be mixed with manures containing ammonia? How can you prove that manures lose their ammonia if mixed with lime?

feather dipped into strong vinegar, when the white fumes will be apparent. The same result is attained if quick-lime is mixed with sal-ammoniac; and a similar result is caused if lime is mixed with the liquid manures of the farm-yard.

For turnips and potatoes, guano should be mixed with an equal weight of the common farm-yard manure; because, alone, it does not contain sufficient organic matter to maintain the land in its most productive state.

A fair proportion for grain and corn crops is about two hundred weight to the acre as a top-dressing; and for potatoes or turnips about the same quantity when mixed with half the amount of common manure, or about three hundred weight of the mixture, per acre.

Where fish are abundant, they may be very profitably used as a fertilizer. They are best made into a compost with marl and earth, and the heaps should be turned or worked over two

Questions.—Why should guano, for some crops, be mixed with common manures? How much guano to the acre is needed for grain and corn crops? How much when mixed with an equal weight of common manure, for potatoes and turnips? Are fish useful as a manure? How *should they be* prepared?

or three times, before use. Fish ought never to be exposed on the surface of the ground; their exhalations, during decomposition, are very offensive, and prejudicial to health.

Amongst mineral manures, the most valuable are nitrate of soda, sulphate of soda (common glauber salts), sulphate of lime (gypsum), kelp, wood-ashes (potash), and lime.

Nitrate of soda is a white, saline (salt-like) substance, found as an abundant natural product in some parts of Peru. It is usefully applied, as a top-dressing, to grass lands and young grain crops. (See Appendix, 24.)

It contains nitric acid and soda; fifty-four pounds of nitric acid and thirty-one pounds of soda form eighty-five pounds of nitrate of soda.

Nitric acid is an intensely sour and corrosive fluid, commonly known as aquafortis. It consists of two gases, nitrogen and oxygen; fourteen pounds of nitrogen and forty pounds of oxygen make fifty-four pounds of nitric acid. Thus

Questions.—Why should not fish be exposed on the surface of the ground? What are the most valuable mineral manures? Where is nitrate of soda found naturally? Of what is it composed? What is nitric acid? Of what composed? *In what* proportions?

you see that, although so corrosive and destructive to life, it contains the same elements as the air we breathe, but mixed in different proportions.

The nitrate of soda, by decomposition, yields nitrogen and soda to the growing crops. About one and a half hundred weight may be spread over each acre.

Sulphate of soda is commonly known as glauber salts. It is composed of sulphuric acid and soda. Sulphuric acid is sulphur combined with oxygen. It is often advantageously applied as a top-dressing to grass lands, turnips, and to young potato-plants. Seventy pounds of dry sulphate of soda contain forty pounds of sulphuric acid and thirty-one pounds of soda.

Common salt is a combination of soda and muriatic acid, the acid commonly known as spirits of salt. It may be applied as a top-dressing, or mixed with the common manure of the yard, or in solution in the water used for slaking

Questions.—What does nitrate of soda yield to the soil? Of what is the sulphate of soda composed? For what is it useful as a manure? What are the proportions of the *components of* sulphate of soda? Of what is common salt *composed?*

quick-lime. It is most beneficial in localities distant from the sea, or where the land is sheltered from the winds by high hills. Near the seashore salt is never needed, because the winds carry with them, in passing over the sea, no small portion of the spray, sprinkling it over the soil to a distance of many miles from the sea-coast.

Gypsum, or plaster of Paris, is a white substance, composed of sulphuric acid and lime. Forty pounds of sulphuric acid and twenty-eight and one-half pounds of lime make sixty-eight and one-half pounds of burned gypsum. The same proportions of acid and lime, with eighteen pounds of water, compose the unburnt gypsum. Native gypsum loses, by calcination, about twenty-one pounds of water, and becomes burned gypsum.

All saline (salt-like) substances should be applied to the soil in still weather, to insure their being equally spread; and immediately before or after a rain, that they may be readily dissolved.

Questions.—Where is salt most usefully applied? Of what is plaster of Paris composed? In what proportions? What is the difference between burned and unburned gypsum? When ought salts to be applied to the soil?

Saline substances are often more advantageously employed, as manures, in a mixed state, than separately. A mixture of nitrate and sulphate of soda has been found to produce a much more beneficial result than the same weight of either of them would have effected; and a mixture of common salt and gypsum will do more good to a crop of beans than an equal weight of either of the articles separately applied.

Kelp is the ashes of sea-weeds; they contain an oxide of sodium, or soda. When attainable in large quantities, they are a valuable manure as a top-dressing to grass lands; and, mixed with common manure, it is of great advantage to crops of turnips and potatoes.

Wood-ashes contain potash, a combination of oxygen with potassium. They are usefully applied to grass lands, destroying the mosses which impede the growth of the grass, and rendering it much more thrifty and luxuriant. They produce the same effect upon young grain and potatoes. Mixed with bones, rape-dust,

Questions.—Are salts best applied mixed, or alone? What is kelp? Of what composed? For what is it valuable as a manure? Of what do wood-ashes consist? What is *their effect* upon the land?

guano, and other manures, they make a very useful compost.

Limestone consists of calcium and oxygen; it is an oxide of the metal, *calcium*. In fifty pounds of limestone we find twenty-eight pounds of lime and twenty-two pounds of carbonic acid. Limestone is hence called the carbonate of lime, and is found in several varieties. It is soft, as chalk; hard, as our common limetone; sometimes yellow, as in magnesian limestones; pure and white, as seen in statuary marbles; black, as the Derbyshire black marble,—besides other varieties.

Marl is a carbonate of lime, often in the form of a fine powder, and usually mixed with earthy matter. Shell-sand, or broken sea-shells, is carbonate of lime mixed with a small quantity of organic matter.

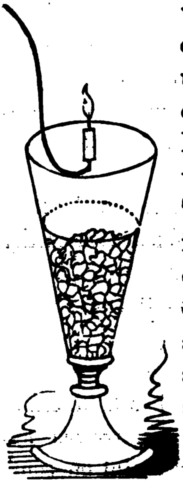
All these varieties of limestone, or carbonate of lime, may be profitably applied to land, either as a top-dressing, or ploughed or harrowed into arable fields. They are most useful on sour,

Questions.—What is limestone? What are the proportions of carbonic acid and lime? What is limestone called? Name some of the varieties of carbonate of lime. How may carbonate of lime be applied to soils?

coarse, mossy grass-lands; and in large quantities on peaty soils, or those containing an excess of organic matter.

Mixed with earth or vegetable matter, or with animal substances, as fish, whale-blubber, etc., they will often be found a very useful compost.

Fig. 21.



If you want to ascertain whether a soil or substance contains lime, you may pour upon a small quantity of it vinegar, or dilute muriatic acid. If lime is present, the mixture will froth up, or effervesce. This bubbling, or effervescence, is caused by an escape of the carbonic acid of the carbonate of lime, because the stronger acids combine with the lime, and therefore let the carbonic acid free.

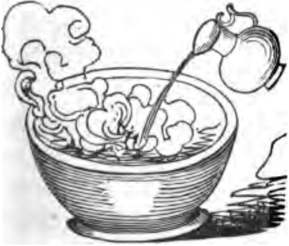
You may easily prove this by putting a little marl, or

Questions. — On what lands is carbonate of lime most useful? How can you ascertain if a soil contains lime? What makes the frothing, or effervescence? How may *you know that* carbonic acid gas is liberated?

chalk, into a wine-glass, and pouring upon it a portion of vinegar, or dilute muriatic acid. That carbonic acid gas is liberated, you may prove by bringing a lighted taper into contact with it, when it will be extinguished.

When limestone, or the carbonate of lime, is burned in a kiln, the carbonic acid is driven off by the heat, and the lime alone remains. It is now called quick, caustic, or hot lime. A ton of limestone yields about eleven and a quarter hundred weight of quick-lime.

Fig. 22.



If water is added to quick-lime, it rapidly absorbs, or drinks it in, giving out a great deal of heat in the form of steam, swelling up largely, and at length falls down into a fine powder. It is now called slaked

Questions. **—What is the effect of burning limestone in a kiln? What is it called after burning? How much quick-lime does a ton of limestone yield? What is the effect of adding water to quick-lime? What is it called after thus falling into powder?**

lime, and is no longer caustic, or hot. The heat produced in the process of slaking is sometimes so great as to set fire to gunpowder placed upon a dry portion of the mass, and a cold baked pie, may be thoroughly heated by being placed upon the slaking lime. Occasionally the heat given off sets fire to the sod with which heaps of lime are sometimes covered in the field.

One ton of pure quick-lime, after slaking, weighs twenty-five hundred pounds, the ton of lime having absorbed and retained five hundred weight of water.

Quick-lime falls to powder gradually if exposed to the atmosphere, because it absorbs the water contained in the air.

In addition to the water from the atmosphere, quick-lime absorbs a portion of its carbonic acid, and is again changed to the state of mild carbonate. You may see this change effected, by pouring a little clear lime-water into a tumbler-glass, which will, in a short time, be covered with a thin film of the carbonate of lime.

Questions. — What change has the quick-lime undergone? How much weight does a ton of lime gain in slaking? Does lime become slaked in any other mode? Does the air effect *any other change* in quick-lime?

When lime has thus repassed into the state of the carbonate, it is more advantageously applied to the land than before it was burned, because in the form of the almost impalpable powder into which it falls by being air-slaked it can be more intimately mixed with the soil.

The quick or unslaked lime acts most promptly upon the land, but the quick and the slaked or mild lime both act in the same manner; they supply the lime which all plants require as a portion of their inorganic food, and, by combining with the acids in the soil, they overcome its sourness and coldness, and convert the vegetable matter into suitable organic food for the plants.

Lime should always be applied on the surface of lands, or, at most, be only just harrowed under the surface.

Quick-lime should be applied to peaty lands, to heavy clay soils, sour arable lands, and to soils containing much vegetable matter.

Questions.—In which form is lime most advantageously applied to soils? In what state does lime act most promptly on the land? How does lime improve the soil? What effect has lime on the vegetable matter contained in the soil? How should lime be applied? To what lands should quick-lime *be applied?*

An equal weight of lime is more effective upon drained, or dry land, than upon a soil which contains an excess of water. Lime should be applied to the soil at such intervals, and in such quantity, as may maintain in the land a full supply of this inorganic and most necessary element. The application of lime requires repetition, because the crops take up and carry off an amount proportionate to their wants, annually; because some portion of it sinks into the subsoil, and is there useless; and, lastly, because the rains are constantly washing some portion of it out of the land.

THE COMPOSITION OF CROPS.

The several kinds of grain mainly consist of three substances,—starch, gluten, and oil, or fat. In one hundred pounds of wheat-flour there are about fifty pounds of starch, ten pounds of gluten, and two to three pounds of oil. One hundred pounds of oats yield about sixty pounds

Questions.—Upon what land is lime most effective? How often should the soil be limed? Why does the lime need to be repeated? Of what do the several kinds of grain *chiefly consist*? In what proportions are these found in one *hundred pounds* of wheat-flour? In one hundred pounds *of oats*?

of starch, eighteen pounds of gluten, and six pounds of oil.

The principal constituent of potatoes and turnips is water. Of the first, one hundred pounds contain seventy-five pounds of water; and of the second, one hundred pounds yield about eighty-eight pounds of water. The quantity of starch in potatoes is about fifteen to twenty pounds to the hundred pounds.

The proportions of the several substances contained in different lots of the same kind of produce will often be found to vary considerably. Some samples of wheat may contain more gluten, some varieties of oats more oil, and some kinds of potatoes more starch.

We have already seen that when vegetables or grain are burned there remains a small quantity of inorganic matter, or ashes. The ashes contain the phosphates of potash, soda, lime, and magnesia; they also contain common salt, and some other saline substances.

Questions.—How much water do one hundred pounds of potatoes contain? How much in one hundred pounds of turnips? How much starch in one hundred pounds of potatoes? Do different lots of the same kind of grain always contain the same proportion of starch, fat, &c.?

USE OF THE PRODUCTIONS OF THE SOIL.

The productions of the soil are, to a large extent, designed for the food of animals. Animals must obtain, from the food they eat, starch, gluten, oil or fat, and saline or inorganic matter, to be enabled to retain health and life.

You will recollect that we proved starch to contain carbon and water; and, as water contains hydrogen and oxygen, starch contains carbon, hydrogen, and oxygen. Sugar also contains the same elements, in a slightly-altered form of combination; and in gum the same elements exist, but again changed in their proportions.

Starch, or substances containing the same elements, must form a part of the food of animals, to supply the carbon which they throw off in the process of breathing.

A healthy man throws off from his lungs daily, in the form of carbonic acid gas, from six to eight ounces of carbon; hence, he must con-

Questions.—What is the great purpose of the productions of the earth? What must animals obtain from their food? Of what is starch composed? Does sugar contain the same substances as starch? Why must the food of animals contain starch, or similar substances? How much carbon does a man throw from his lungs daily?

sume daily some substance which will yield that amount of carbon to his system, or he must soon become the subject of impaired health. Fifteen ounces of starch contain about seven ounces and three-quarters of carbon; so that his food must be equal, in the carbon it contains, to a little more than fifteen ounces of starch.

The carbonic acid gas thrown off from the lungs is diffused in the atmosphere, to be again taken up by plants, again by them to be re-transformed into starch, or substances similar in composition thereto. Thus you see how beautifully, in the economy of nature, the processes of reproduction are perpetuated. The same carbon is again and again transformed by the plant into starch, and by the animal into carbonic acid. The animal transforms the carbon into carbonic acid gas, by a process of combustion, necessary to keep up its warmth; and, in the process of vital combustion, a portion of the carbon combines with a portion of the oxygen of

Questions.—How much starch, or its equivalent, must a man consume daily? What becomes of the carbonic acid gas thrown from the lungs? Is the same carbon again and again reproduced and consumed? How is the carbonic acid *gas produced* by the animal from the carbon taken in his *food?*

air taken into the lungs, and forms carbonic acid gas.

Gluten must form a part of the food of animals, for the purpose of supplying to the muscles, or lean part of the body, new substance to make good their daily loss. Every portion of the body is, by a similar change of atoms, constantly being formed anew; and, as the daily added portions have fulfilled their purpose in the structure and uses of the several organs and their adaptations, they are again, in the form of excrementitious matter (sweat, urine, dung, carbonic acid gas, etc.), thrown off as waste.

Gluten supplies the waste of muscles, because the gluten of plants and the muscles of animals are chemically identical; that is, they contain the same elements. If an animal eats more gluten in its food than is required to supply muscular waste, the excess thereof is transformed into fat.

Food which contains the most fatty matter will fatten an animal in less time than those

Questions.—Why must gluten be contained in the food of animals? Why does gluten supply muscular waste? What becomes of any excess of gluten contained in the food? What kind of food will most quickly fatten an animal?

varieties which are deficient in that substance. It is because of the fatty matter contained in oil-cake, that it is so efficient in improving the condition of stock to which it is fed.

Phosphate of lime, and other saline or inorganic substances, must also be contained in the food of animals, to supply the constant waste of the osseous system (the bones), the salts in the blood, etc.

The gluten and saline matter also serve another purpose besides supplying the constant waste of the system; they daily add to the weight of the body of the animal. Hence you see why it is that a growing animal requires much more of these kinds of food than one which has attained his growth. The full-grown animal has only its daily waste to make good; but the growing animal has also an additional amount of new substance to make daily, besides that quantity needed to supply the daily waste of its system; if it did not do this, it could never become larger, or increase in weight.

Questions.—Why should the food of animals contain phosphate of lime, and other inorganic substances? What other purpose does gluten and saline substances subserve? Why does a *growing* animal require more of those substances *than a full-grown* one?

If the same weight and kind of food be given daily to a growing animal and one which has attained its growth, the dung of the full-grown animal will contain most of the organic and inorganic substances necessary in the manure; because the growing animal must, for the reason already given, retain more of those substances which the food contained.

It is for this reason that the manure made by fattening stock is much more valuable than that made by growing stock. The former take up and retain only the oil and starch the food contained, while the latter take up and retain the greater part of all its organic and inorganic constituents.

If it was desired to make the largest quantity of beef or mutton from a ton of oats or turnips, the stock should be kept in a warm and sheltered place,—partially secluded from the light, but where they could obtain good and wholesome

Questions.—From the same weight and kind of food, will the manure made by a growing or full-grown animal be most valuable? Why is the manure made by a full-grown animal more valuable than that of a growing animal? How would you manage to make the most beef or mutton out of a ton of oats, turnips, or other food?

air. In the process of fattening a full-grown beast, it should be kept warm, fed upon oil-cake, oats, or corn, with abundance of turnips, and be allowed to take only limited exercise.

If the amount of manure to be made is the object of the farmer's efforts, then his stock should be kept in a cooler and less sheltered locality, and where they can take abundant exercise.

When the farmer is anxious to obtain the *largest* quantity of milk, his cows should be fed on good juicy grass, turnips, corn mashes, and other food containing abundance of water,— and they should also be freely supplied with water. But, if the *quality* of the milk was more desirable than the *quantity*, then the food should be principally dry, as oats, beans, bran, corn, clover-hay, etc.; and no more water should be given than necessary for health.

If the milk is designed for butter, then the food of the cow should be rich in fatty substance,

Questions. — What would you do if you wanted an abundance of good manure? What would you do to obtain the largest quantity of milk? What course would you pursue if you wanted milk of the best quality? What, if the milk was designed for butter?

as oil-cake, oats, barley, corn meal, good sound hay, and a moderate quantity only of turnips. But, if the milk is designed for cheese, then beans, peas, vetches, or clover-hay, should be fed, because those articles of food are richer in curd substance.

For cattle the food should always be sweet and fresh, and if the several articles, as beans, turnips, corn-meal, etc., were first boiled, and then allowed to become cold before being fed to the stock, the advantages gained would more than repay the additional labor.

The food of hogs is better given slightly soured. The vegetable refuse, meal, potatoes, etc., should be boiled and mashed together, and, thus mixed, allowed to sour; for it has been found that more and better pork is thus made than when the hogs' food is fed perfectly sweet.

Apples are an excellent food either for hogs or other stock; and they would be thus more profitably used by the farmer than converted into cider.

Questions. — What course would you pursue, if you intended your milk to be made into cheese? In what state is the food of cattle best given? How is the food of pigs best given? Why should the food of pigs be cooked, and slightly sour? Are apples a good article of food for stock?

Stables, cow-houses, pig-styes, hen-ho
etc., should be well ventilated, and kept clea
sweet; and they ought also to be so arrang
to be kept *warm* and *dry* in cold and
weather. The farmer can keep his stock thr
the winter on one-third less food, and i
equally good condition, in a good, *warm*,
fortable stable or out-house, than in an exp
damp, cold, and only half-enclosed out-hou
barn.

Questions.—How should stables, cow-houses, et
kept? What advantage to the farmer are warm st
cow-houses, etc.?

APPENDIX.

1. THE teacher should burn a piece of wood or straw in the flame of lamp (Fig. 1), and explain the result.

2. Burn a piece of charcoal before the class. Notice the dissimilarity between the diamond and charcoal, though chemically the same body.

3. Provide a tall glass (Fig. 2) and a piece of wire, to the end of which a small bit of wax taper is secured. Put into the glass a few shreds of zinc or iron; pour upon them a little sulphuric acid diluted with two or three times its bulk of water. Hydrogen gas forms rapidly. Now introduce the lighted taper; an explosion will be heard, and the taper is extinguished. Make the gas in the same manner in a vial (Fig. 3), and show how the gas burns. Remove the cork, and put the taper into the vial. It is instantly extinguished, and the gas ignited, which burns at the mouth of the bottle. Slowly withdrawing the taper, it will be relighted by the *burning hydrogen*.

4. Oxygen gas is most easily prepared by mixing together equal weights of chlorate of potash and black oxide of manganese, putting the mixture into a common Florence flask, and applying a spirit-lamp (see Fig. 6). With a piece of India-rubber tube, or thin lead pipe, the gas may be collected in bottles, as seen in Fig. 8. When filled, they may be corked tightly. Into a bottle of oxygen put a lighted taper (Fig. 4); show the brilliancy of the flame. In the same manner introduce a small piece of ignited charcoal; and next, a piece of very thin iron wire, to the lower end of which a little bit of brimstone is secured, and ignited. Show how the iron is consumed.

Before igniting the wire weigh it, and again weigh the mass after burning, and it will be found to have increased in weight, by combining with some of the oxygen, forming oxide of iron. Fig. 5 shows a method of exhibiting some of the effects of oxygen, without any of the ordinary apparatus. Into an open tube a small quantity of the mixture of chlorate of potash and oxide of copper may be placed, and the heat of a lamp applied.

5. Nitrogen may be prepared by mixing sal-ammoniac with half its weight of saltpetre, both in fine powder and perfectly dry, and heating them in a retort over a lamp. The gas may be collected as in Fig. 8. Put into a bottle of nitrogen a lighted taper; its flame is instantly extinguished, and the gas is not ignited, as was the hydrogen. Nitrogen is also formed by burning phosphorus in a bottle of common air; the oxygen combines with

the phosphorus, forming phosphoric acid, and the nitrogen alone remains. After the combustion of the phosphorus, the water will have risen in the bottle so as to fill it one-fifth, the quantity of oxygen the air contained; the remaining four-fifths are nitrogen.

6. Let the teacher submit to the class specimens of common *pearlash*, of washing-soda, of quick-lime, of *calcined magnesia*, oxide (rust) of iron, silicia, as flint or quartz, chlorine gas, a bottle containing sulphuric acid, phosphoric acid in the form of burnt bones, etc. By this mode of ocular demonstration his class will soon become acquainted with the names and appearances of these several articles.

7. Let the class taste a dilute solution of potash, that they may recognize the alkaline taste.

8. Exhibit a crystal of common washing-soda, and let the class taste it.

9. Let the class look at and cautiously taste a piece of quick-lime. Pour upon it a little water, that it may fall to pieces. Explain the word *slake*, as applied to this process.

10. Describe metals as bodies having more or less lustre, weight and malleability. Hammer a piece of lead and a piece of stone, and explain the difference in the result.

11. Let the teacher explain the meaning of oxidation. When oxygen unites with metals, they form new substances, unlike the metal from which they were formed. Put a little red lead (oxide of lead) into the bowl of a tobacco-pipe, filled with finely-pulverized charcoal; then let the pipe-head become red-hot, by placing it in the fire, or in the flame of a spirit-lamp. The oxygen combined with the lead will have united with some of the charcoal, forming carbonic acid gas, and the lead will be found again reduced to the metallic state.

Next put a little of the red oxide of mercury into a small retort, and apply a spirit-lamp (see Fig. 8). The oxygen will be driven off by the heat, and the bright fluid metal, mercury, may be collected, as it trickles down the beak of the retort.

12. Put a little black oxide of manganese into a Florence flask, and pour upon it a portion of muriatic acid, then apply the heat of a small lamp. The chlorine will be set free, and may be collected in bottles filled with hot water, as seen in Fig. 8. It cannot be collected over cold water, because cold water rapidly absorbs the gas. Chlorine being heavier than the atmosphere, it may be collected in bottles filled only with common air, by attaching the India-rubber tube to the neck of the flask, and allowing it to reach the bottom of the bottle to be filled. It will thus gradually force the air out of the bottle, and occupy its place. Be careful not to inhale the gas; and experiments with chlorine should be performed under an open window, or in the open air. Put a taper into a bottle of chlorine; it is instantly extin-

guished. Pour it from a bottle upon a lighted taper (Figs. 10 and 11), proving its density to be greater than the atmosphere. Put a little bit of phosphorus into a bottle of chlorine; the phosphorus will be ignited, and so will filings of zinc, if allowed slowly to fall into a bottle of this gas. Show its bleaching powers by its action on an infusion of red cabbage, and other vegetable colors.

13. Put a piece of straw into a little sulphuric acid, and show its decomposing power, as it charrs or changes the straw into carbon. Explain that, although sulphuric acid exists in plaster of Paris, alum, Glauber salts and Epsom salts,—all of which should be exhibited to the class,— they are not possessed of its burning or corrosive properties. Add water, very cautiously, to a portion of the acid placed in a tea-cup, and show the great heat produced by their combination. When very largely diluted, let the solution be tasted, that *acidity* may be recognized in contradistinction to the taste of alkalies. Add a little sulphuric acid to an infusion of red cabbage, showing that acids redden vegetable substances; then to the reddened solution add any alkali, until the acid is neutralized, and the alkali is slightly in excess, and show the production of the blue color.

Next, add an alkali to the infusion of red cabbage, and show the change effected by alkalies. Then neutralize the alkali by the addition of sulphuric acid, and as soon as the acid is slightly in excess the bright red color will be again produced.

14. Ignite a very small piece of phosphorus in the air; the white fumes are phosphoric acid. Fill a saucer with water, let a little piece of cork float upon it; place upon the cork a minute piece of phosphorus, ignite it, and invert over it a large tumbler-glass, or a wide-mouth glass bottle. It is at once filled with dense white fumes, which are phosphoric acid. After a while the fumes disappear, the water has dissolved the phosphoric acid, and the glass only contains the nitrogen which entered into the composition of the air. Phosphorus must be used very cautiously, and always cut under water; and it should never be handled, as the heat of the skin is sufficient to ignite it. It should be always taken up with a pair of tweezers, or small forceps.

15. Put a few pieces of limestone, or of the common soda of the shops, into a tall glass (Fig. 2), and pour thereon a little dilute muriatic acid. Effervescence commences with the evolution of carbonic acid gas. Put into the glass an ignited taper; it is extinguished, but the gas is not inflamed like hydrogen. Then make the gas in a Florence flask (Fig. 6), by the introduction of the lime and dilute acid, and collect it in bottles in the same way as chlorine was collected, because it is much heavier than the atmosphere. Put the lighted taper into an empty glass (Fig. 10), and pour upon it carbonic acid gas from a bottle or another glass. The taper is extinguished, as though water had been poured upon it, instead of an invisible gas. Light a common *candle (Fig.* 11) and pour upon it the gas contained in *an apparently* empty tumbler; the flame of the candle

is instantly extinguished. Now, while the wick continues red, plunge the candle into a bottle of oxygen, and it will be again enkindled into a flame.

16. Introduce a piece of kindled charcoal into a bottle of oxygen gas. When the charcoal no longer burns, which it will, for a short time, with great brilliancy, put a lighted taper into the bottle, and the presence of carbonic acid gas will be recognized by its being instantly extinguished.

17. To form *humic acid*, the teacher will dissolve a little common soda in water, boil the solution upon finely-powdered peat, or rich dark soil. Pour off the solution when it has become clear. The soda has united with the humic acid. Now add a little diluted muriatic acid; the muriatic acid will combine with the soda, forming muriate of soda, which remains in the solution, and the humic acid, being liberated, falls down in brown flakes. This humic acid consists of carbon and water only, or of carbon, hydrogen and oxygen.

18. Mix a little flour with water into a dough; put it into a large tumbler full of water, over the top of which is tied a piece of fine muslin. Shake it a while, then pour off the water, carrying with it the starch; add fresh water until it comes away quite clear. Let the water containing the starch stand a while, so that the starch may settle to the bottom and be collected. Then exhibit the gluten remaining after all the starch has been thus washed away.

19. The following table should be printed on pasteboard, and suspended on the wall of the school-room, or written legibly on the black-board :

72 lbs. of woody fibre contain carbon 36 lbs., water 36 lbs.
81 lbs. of dry starch or gum contain carbon 36 lbs., water 45 lbs.
85½ lbs. of loaf-sugar contain carbon 36 lbs., water 49½ lbs.
63 lbs. of humic acid contain carbon 36 lbs., water 27 lbs.

Let the teacher direct attention to the fact that these very different appearing substances all contain the same elements; that in the quantities designated they all contain thirty-six pounds of carbon, but that the hydrogen and oxygen, in the form of water, differs in quantity in each.

20. Let the teacher remark the difference between elementary and compound bodies. Compound bodies can be divided into two or more elementary bodies. Thus starch may be divided into carbon, hydrogen and oxygen ; but these elements cannot be again subdivided, or decomposed into other bodies. Water is a compound body, containing hydrogen and oxygen. Carbonic acid contains carbon and oxygen. The air we breathe contains nitrogen and oxygen. He may add to these illustrations *ad libitum*.

21. (See Fig. 15.) Explain the meaning of the word carbonaceous, and refer again to the organic and inorganic forms of matter.

22. The words *dissolve* and *solution* should be practically illustrated. Dissolve some salt and sugar in a

tumbler of water. They have disappeared. What has become of them? They are held in solution in the water. Now let the water be boiled down, or slowly evaporated, and the salt and sugar will become again visible in the form of crystals.

Dissolve in water as much alum as it can take up. When the water can dissolve no more it is said to be saturated. Let the solution of alum remain undisturbed for a few days, in a warm place, and, as the water is carried off by evaporation, the alum will be restored to the crystalline form. Explain how the soil becomes dry and parched, in the hot weather of summer, by this process of evaporation.

23. The tables on the 43, 45 and 47 pages, should be printed on a large sheet of pasteboard, and hung up in the school-room. They will suggest many important questions, and familiarize the class with the facts they contain.

24. Explain the terms by which chemists denote the different kinds of saline substances, or of alkalies in combination with acids. Thus, when nitric, sulphuric, muriatic, carbonic or phosphoric acid, combine with the alkali soda, they form the nitr*ate*, sulph*ate*, muri*ate*, carbon*ate* or phosph*ate* of soda. If they combine with lime, then we have the nitr*ate*, the sulph*ate*, the muri*ate*, the carbon*ate* or the phosph*ate* of lime.

When the nitr*ous* or sulphur*ous* acids combine with alkalies, the salts formed are called sulphites; thus we have *the sulphite* of soda, or the nitrite of lime.

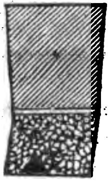
When we speak of the sulphate of soda, we mean a substance called a salt, composed of soda, which is called the base, and sulphuric acid. Hence, the phosphate of lime is a salt containing lime, the base, and phosphoric acid; and carbonate of potash, a salt containing potash as the base, and carbonic acid.

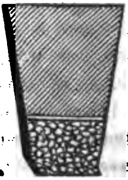
25. In addition to the four elementary bodies, carbon, hydrogen, oxygen and nitrogen, which constitute the organic part of plants, some of them also contain small quantities of sulphur, and larger quantities of phosphorus. These additional organic elements are obtained from the sulphuric acid and phosphoric acid contained in the soil.

Sulphuric acid is a combination of sulphur and oxygen. The plant decomposes the acid, retaining a portion of its sulphur, and throwing off the oxygen with which it was combined; and the same explanation may be applied to the phosphorus some plants contain.

26. Reference has been made to under-draining wet lands; we annex the methods whereby this result may be attained.

Good drains may be made with small stones, as shown in the annexed sectional diagrams. They are very effective if well made, but not so useful or durable as those constructed of tiles. The small stones should be covered by a

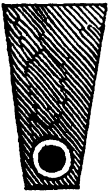




sod, or turf, the grass downwards, and the earth firmly trod down over them.

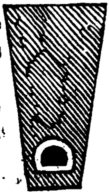
Tile-drains may be constructed of a variety of forms. When laid down the slopes of the lands, and about twenty to thirty feet distant, tile-tubes of a single inch diameter will carry off all the surplus water, unless it is unusually abundant. We annex several forms of tiles, adapted for different kinds of lands, and the mode of their insertion in the ground.

1



Nos. 1 and 2 are available where the quantity of water is not greatly in excess; and Nos. 3, 4 and 5 are also applicable where the surplus water is not too great.

2



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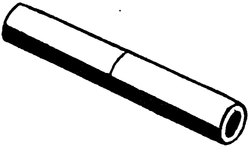

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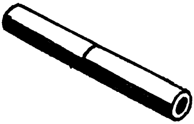
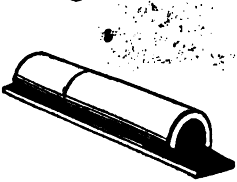
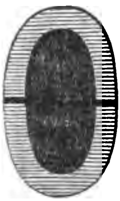




6



No. 6 is the common oval drain, designed and adapted for very wet lands, or for lands where only a slight fall can be obtained.

27. All fertile soils contain gypsum. Sometimes it exists in sufficient quantity for all the purposes of successful agriculture, without any artificial supply; and in localities near the sea-coast the sulphate of soda supplies its deficiency, if any exists. But where gypsum is naturally abundant in the soil, it is profitably scattered over the manure-heap, the stable, and the urine-tank, for the purpose of arresting the escape and loss of the volatile ammonia, which it transforms into the sulphate, which is not volatile. Scattered also on corn and potato drills, it is very serviceable in arresting the ammonia which a spell of dry weather causes to ascend from the manure beneath the soil, and in the form of the sulphate, retaining it at the surface, ready to be again carried into the soil with the first rain which falls.

28. A knowledge of the chemical constituents (the principal organic elements) which enter into the composition of urine, is of much practical value to the scientific farmer.

Carbon,	20.0
Hydrogen,	6.6
Oxygen,	46.7
Nitrogen,	26.7
	100.0

In the process of decomposition this substance unites with water, forming carbonate of ammonia, which is rapidly lost in the atmosphere, unless absorbed by earth, peat, swamp-soil, etc., or changed into the non-volatile sulphate of ammonia by gypsum, or sulphuric acid. In addition to the urea, and some other organic matter, urine contains potash, soda, and phosphatic salts.

29. We annex an analysis of 100 parts of stable manure, dried at the temperature of boiling water.

1st. The organic part:

Carbon,	37.40
Hydrogen,	5.27
Oxygen,	25.51
Nitrogen,	1.76
Ashes,	30.05
	100.00

2nd. Inorganic components of 100 parts of ashes:

Potash,	3.32	Soluble in water.
Soda,	2.73	
Lime,	0.34	
Magnesia,	0.26	
Sulphuric Acid,	3.27	
Chlorine,	3.16	
Silicia,	0.04	
Phosphate of Lime,	7.11	Soluble in Hydrochloric acid.
" " Magnesia,	2.26	
" " Oxide of Iron,	4.68	
Carbonate of Lime,	9.34	
" " Magnesia,	1.63	
Silicia,	27.01	
Insoluble sand, etc.,	34.96	

By long exposure to the air and weather, much of the most valuable portion of the organic part of the manure escapes into the atmosphere, and another considerable portion is washed away and carried off. From these causes the soil is deprived of much of the most valuable and fertilizing portion of the manure, and hence the crops are also hindered in their growth and perfection. The intelligent farmer will, therefore, protect his manure from these sources of loss; and he will be also enabled, by reference to the tables already given, to supply an additional quantity of those substances which the land may need, in order to insure the best and most profitable crops.

30. In the progress of this work we have had occasion to refer to certain elementary bodies, or substances, whose combinations make up the organic part of plants. These elementary bodies are chemically expressed by definite characters, or symbols, and, as their use is universally adopted, we have subjoined the symbols of all the principal substances to which reference has been made.

31. In addition to the symbol, a numeral will be noticed, called the EQUIVALENT, which means the combining number. Thus the symbol of Oxygen is O — its equivalent, or combining number, 8; the symbol of Nitrogen is N — its equivalent, 14.15.

32. Bodies, in forming chemical combinations, unite *in certain fixed* or definite proportions, and these com-

bining proportions are observable whether two elements combine to form a single compound, or half a dozen different compounds; and the successive combinations are multiples, or simple ratios, which may be expressed by the numerals 1, 2, 3, 4, 5, etc., or 1, 1½, 2, 2½, 3, 3½, etc.

33. In the first order, it will be seen that the quantities expressed by 2, 3, 4, etc., are multiples of the first; and in the second series, the quantities are increased in each combination one-half of the first.

The following illustrates the combinations of Nitrogen and Oxygen, and they will be found to follow the first series of numbers; for, while the Nitrogen remains stationary, the Oxygen in each succeeding combination is a multiple of 8, its equivalent number.

COMBINATIONS OF NITROGEN AND OXYGEN:

Nitrous oxide,	Nitrogen, (*N*)	14.15 :	Oxygen, (*O*)	8	1
Nitric oxide,	do.	14.15 :	do.	16	2
Hyponitrous acid,	do.	14.15 :	do.	24	3
Nitrous acid,	do.	14.15 :	do.	32	4
Nitric acid,	do.	14.15 :	do.	40	5

34. The annexed combinations of Oxygen with Manganese illustrate the second series of figures, wherein each succeeding number is increased by the addition of half of the first, or equivalent.

COMBINATIONS OF MANGANESE AND OXYGEN:

Protoxide of Manganese,	(*Mn*)	27.7 :	Oxygen,(*O*)	8	1
Sesquioxide	do.	27.7 :	do.	12	1½
Peroxide	do.	27.7 :	do.	16	2
Not yet discovered	do.	27.7 :	do.	20	2½
Manganic acid	do.	27.7 :	do.	24	3
Permanganic acid	do.	27.7 :	do.	28	3½

It will be seen that the fourth line in the above list is nameless, no combination having yet been discovered to complete the series. That a form of matter exists, and may yet be discovered, to fill the vacancy, is most probable.

35. Symbols and Equivalents of the Elementary Substances referred to in this work:

NAME.	SYMBOL.	EQUIVALENT.
Carbon,	*C*	6.12
Hydrogen,	*H*	1.
Oxygen,	*O*	8.
Nitrogen,	*N*	14.15
Potassium (Kalium),	*K*	39.15
Sodium (Natrium),	*Na*	23.3
Calcium,	*Ca*	20.5
Magnesium,	*Mg*	12.7
Silicion,	*Si*	22.5
Chlorine,	*Cl*	35.42
Sulphur,	*S*	16.1
Phosphorus,	*P*	15.7
Iron,	*Fe*	28.0
Manganese,	Mn	27.7
Aluminum,	Al	13.7

These symbols are, in most instances, the first letter of the Latin word expressing the article named. But it will be seen in the table that some substances have a small letter added to the capital; the necessity for this addition is easily explained. The symbol of Carbon is *C*, but Calcium (the Latin word for lime) also begins with C, — hence, to avoid all confusion in the symbols, Calcium is designated by *Ca*. In the same manner, *N* is the symbol of Nitrogen, and *Na* of Natrium, or Soda.

36. Table of the principal Compound Bodies named in this work :

NAME.	ELEMENTS.	EQUIVALENT.	SYMBOL.
Sulphuric acid, ...	S 16.1 . O 24 .	= 40.1 . .	SO_3
Nitric acid, ...	N 14.15 . O 40 .	= 54.15 . .	NO_5
Hydrochloric (Muriatic) acid,	Cl 35.42 . H 1 .	= 36.42 . .	HCl
Phosphoric acid, ...	P 31.34 . O 40 .	= 71.4 . .	$P_2 O_5$
Carbonic acid, ...	C 6.12 . O 16 .	= 22.12 . .	CO_2
Water, ...	H 1. . O 8 .	= 9. . .	HO

In examining the symbols, there will be seen appended to some of them small figures; thus, O_3. The use of those figures is important, and should be remembered. Let us examine the first symbol, that of Sulphuric acid. We find its elements to be Sulphur (*S*) 16.1, which, on reference to the first table of symbols, is seen to be its equivalent or combining number; and Oxygen (*O*) 24, reference to the table of symbols gives 8 as the combining number of Oxygen; hence, in the number 24 we find three times 8, or 3 equivalents of Oxygen. Then we learn that to form Sulphuric acid one equivalent of Sulphur is combined with three equivalents of Oxygen, and the symbol SO_3 indicates that combination.

The symbol of Phosphoric acid is P_2O_5; hence. there are two equivalents of Phosphorus combined with five equivalents of Oxygen requisite to make Phosphoric acid. An equivalent of Phosphorus is 15.7, multiplied by 2 gives 31.4; an equivalent of Oxygen is 8, multiplied by 5 gives 40; and 31.4 added to 40 = 71.4, which is the equivalent of Phosphoric acid, as expressed by its symbol P_2O_5.

NAME.	BASE.	ACID.	EQUIVALENT.	SYMBOL.
Sulphate of Lime,	1 eq. +	1	68.6	CaO, SO_3
" " as gypsum, with 2 eq. of water 18			86.6	
Carbonate of Lime (Marble),	1 eq. +	1 eq.	50.62	CaO, CO_2
Sulphate of Soda,	1 eq. +	1 eq.	71.4	NaO, SO_3
" " in crystals, with 10 eq. of water 90			161.4	
Nitrate of Soda,	1 eq. +	1 eq.	85.45	NaO, NO_5
Chloride of Sodium (com. salt),	1 eq. +	1 eq. of Cl	58.72	NaO
Nitrate of Potassa (saltpetre),	1 eq. +	1 eq.	101.3	KO, NO_5
Carbonate of Magnesia,	1 eq. +	1 eq.	42.82	MgO, CO_2
Sulphate of Ammonia,	1 eq. +	1 eq.	66.25	NH_4O, SO_3
Nitrate of (oxide of) Ammonia,	1 eq. +	1 eq.	80.3	H_4NO, NO_5
Muriate of Ammonia,	1 eq. +	1 eq.	53.57	H_4N, HCl

The teacher should analyze and explain the above symbols, showing his class the value of the numerals, and the part they play in the formation of the articles they represent. Thus, Sulphate of Lime is composed of CaO and SO_3; Ca, the symbol of Calcium (20.5), and O, the symbol of Oxygen (8), represent that combination called Oxide of Calcium; one equivalent of this Oxide of Calcium is combined with one equivalent of Sulphuric acid; S, the symbol of Sulphur (16.1), and O_3, the symbol of Oxygen (8), multiplied by 3. Now, we may show the formation of the Sulphate of Lime, and the mode of obtaining its equivalent number, by the following diagram :

Sulphate of Lime,	1 eq. of Oxide of Calcium contains	Ca	. 1 eq.	20.5
		O	. 1 eq.	8.0
	1 eq. of Sulphuric acid contains	S	. 1 eq.	16.1
		O_3	. 3 eq.	24.0
The equivalent number of Sulphate of Lime, ...				68.6

37. Composition of Starch, Gum and Sugar :

Starch, ...	$C_{12}\ H_{10}\ O_{10}$
Gum and Cane Sugar,	$C_{12}\ H_{11}\ O_{11}$
Sugar of Milk, . . .	$C_{12}\ H_{12}\ O_{12}$
Grape Sugar, . . .	$C_{12}\ {}_{14}\ {}_{14}$

The above table shows that while in all the articles named the Carbon remains the same, they are almost identical in their chemical constitution,—the only difference being the slight addition of water, or the elements of water ; this will be more readily apparent from the following view :

Starch, ...	$12\ C + 10$ water.
Cane Sugar and Gum,	$12\ C + 10$ water $+ 1$ water.
Sugar of Milk, . .	$12\ C + 10$ water $+ 2$ water.
Grape Sugar, . . .	$12\ C + 10$ water $+ 4$ water.

Hence, for the same number of equivalents of Carbon, Starch contains of water or its elements 10 equivalents ; Cane Sugar and Gum, 11 equivalents ; Sugar of Milk, 12 equivalents ; and Grape Sugar, 14 equivalents.

38. Cultivation is the economy of force ; while science teaches us the simplest means of obtaining the greatest results with the smallest expenditure of power, and the *consequent* development of the largest amount of force.

39. A tribe of hunters confined to a limited space cannot increase in number beyond a fixed and early attained point. Respiration demands Carbon, and the savage must obtain the Carbon he consumes in respiration from the flesh of the animals he eats. The animals collect from the vegetable products the constituents of their organs and blood, and these are yielded to the savage who lives alone by the chase, unaccompanied by those non-azotized substances which, during the life of the animals, served to support the respiratory process. Whenever man is confined to a flesh diet, the Carbon of the flesh and blood must take the place of Starch and Sugar, those great sources of the supply of Carbon to the grain-eating animals and civilized man.

40. Fifteen pounds of flesh contain no more Carbon than four pounds of Starch. A savage who could maintain life for a given number of days with one animal, and an equal weight of starch, if confined to flesh alone, would require five such animals in the same number of days.

41. From the consideration of these, and many similar facts, how full of interest becomes the connection between agriculture and the multiplication of the human family! Agriculture has but one object, and that is, to produce from the smallest possible space the largest possible amount of nutritious and life-sustaining substances.

42. A cow, or a sheep, eats almost uninterruptedly *from sunrise to sunset* (whilst at large in the meadow), *and yet it* **wastes** nothing of the amount it consumes;

for all that is not demanded for the mere supply of the waste of its body in the maintenance of life is converted into organized tissues; the excess of blood made is transformed into cellular and muscular substance.

43. The stall-fed animal eats, and reposes merely for the purpose of digestion. It consumes, in the form of nitrogenized substances, much more food than is requisite to supply the waste effected by the vital processes; and at the same time it eats much more non-nitrogenized food than is required for respiration and the production of animal heat. The excess of Carbon thus taken up by the animal is not converted into muscle (lean meat), but is transformed into fat, — a substance which, in the natural state, is only found in small amount in the brain and nerves.

44. The flesh of wild animals is almost wholly devoid of fat, while the flesh of stall-fed animals is covered with a thick layer of that substance. But, if the stall-fed animal is permitted to go at large, or is put to hard labor, the excess of fat soon disappears.

45. A horse can be kept in a perfectly good condition if he can obtain as food fifteen pounds of hay and four and a half pounds of oats, daily.

46. A hog fed with highly nitrogenized food makes flesh (lean meat or muscle), but if fed upon diet containing much starch (Carbon) it acquires little flesh, with a great excess of fat. It is because apples contain

sugar (Carbon) that they are so useful in fattening hogs, or other stock.

47. Every article of food may be divided into two classes, *nitrogenized*, and *non-nitrogenized;* the former alone are capable of transformation into blood, and may be called the *nutritious elements*. Amongst the most important of these are vegetable fibrine, vegetable albumen, animal flesh and animal blood.

48. The non-nitrogenized substances which enter into the food of man and beast may be designated the *elements of respiration;* amongst these are fats, starch, gum, and sugar.

END.